[Color Models]

→ Color is a fundamental attribute of our viewing experience.

→ The perception of ~~light~~ color arises from light energy entering into our visual system, so there is a basic relationship between light and perception of color.

Light and color

→ Light is electromagnetic energy in the 400 to 700 nm (nano meter) wave length (λ) range of the spectrum (or we can say a narrow frequency band.

→ Each frequency value within the visible band corresponds to a distinct color:

→ At a low-frequency end is a red color (4.3×10^{14} Hz) and the highest frequency we can see the violet color (7.5×10^{14} Hz).

→ spectral color range from the reds through orange and yellow at the low frequency and to greens, blues and violet at the high end.

→ Since the light is an electromagnetic wave, we can describe the various colors in terms of either frequency (f) or wave length (λ) of the wave.

→ When light is incedented upon an object, some frequencies are reflected and some are absorbed by the object.

→ The combination of these frequencies present in the reflected light determines what we perceive as the color of the object.

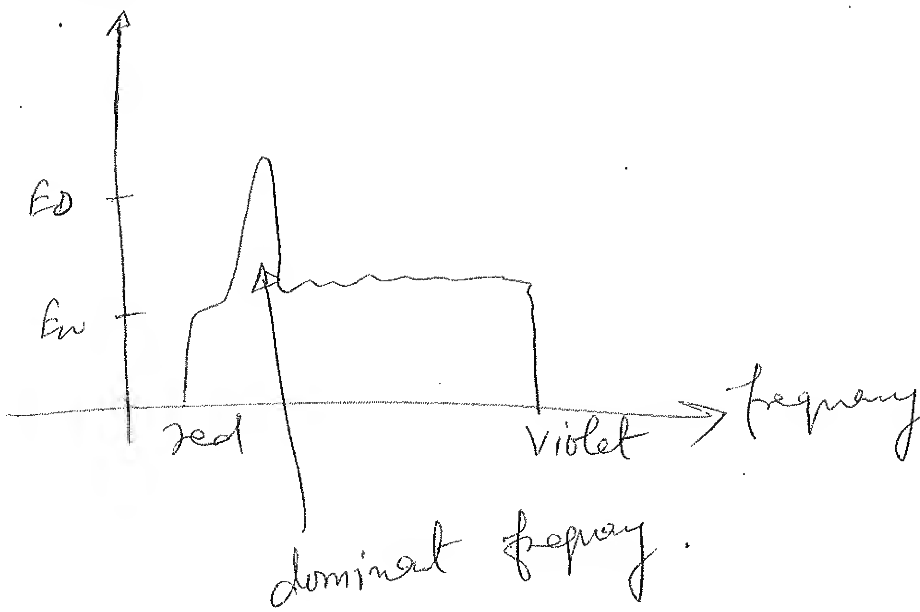
→ If low frequencies are predominant in the reflected light, the object is described as red.

→ The dominant frequency is called the hue or simply the color of the light.

⇒ When we view a light source, our eyes respond to the color (dominat frequency) and two basic sensations. One of these is called as brightness, which is perceived intensity of the light and measured as energy emitted per unit time.

⇒ The second sensation is the purity or saturation of the light.

These three characterstics, dominant frequency (hue), brightness and saturation (purity of color) are commonly used as the color characterstics.



→ We can calculate the brightness of the color using the curve area shown in the previous page figure in dominant frequency range.

→ Purity or saturation can be calculted using the difference between $(E_D - E_W)$.

→ Larger the value of E_D, the more pure the light. We have the 100% purity when $E_W = 0$ and 0% purity when $E_W = E_d$.

Color models

→ If two or more color sources combine to produce wide range of colors then we call it as a color model, and produced range of colors is called as color gamut.

→ An artist creates a color painting by mixing color pigments. ~~and~~ for making lighter color the white pigment and to make the color darken the black pigment.

According to the above phenomenon in computer graphics following color models are used:

(i) RGB color model
(ii) YIQ color model
(iii) CMYK color model
(iv) HSV color model.
(v) HLS color model.

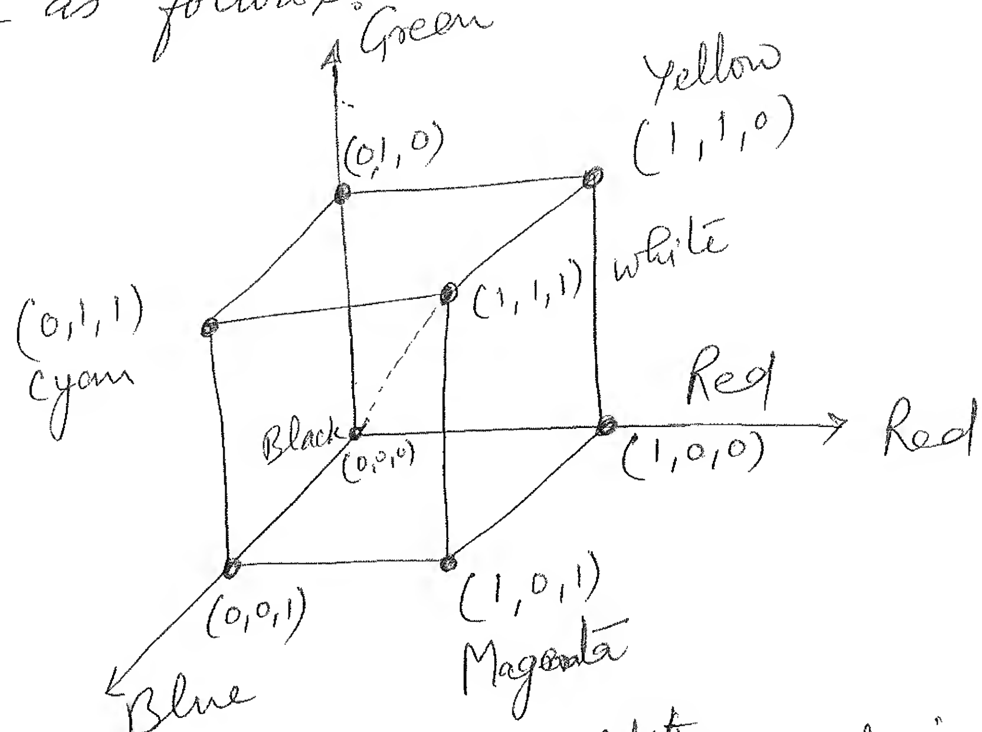
RGB color model

Based on the theory of vision, our eye perceive color through the stimulation of three visual pigments in the cone of the retina.

→ These visual pigments have a peak sensitivity at wavelengths of about 630 nm (red), 530 nm (green) and 450 nm (Blue).

→ Using these three color primaries (Red, Green, Blue) the colors are displayed on the monitor.

→ The model can be represented using the unit cube as follows:



→ The RGB color model is <u>additive</u> and intensities are added (of primary color) to produce other colors.

$$C_\lambda = RR + GG + BB$$

where the values of (R,G,B) are assigned in the <u>range 0 to 1</u>

→ The dashed diagonal line from (0, 0, 0) to (1, 1, 1) represents the gray shade between black and white.

YIQ color model

→ Whereas RGB color monitor uses seperate signals for R, G, B components of an image, a television monitors uses a single composite signal. The NTSC (One of the International Committee to specify the color standards) color model is ~~YIQ~~ based on YIQ for television.

Here Y ⇒ represents the brightness

I and Q ⇒ represents the hue and purity

→ The combination of R, G, B intensities are chosen to set the Y value. eg. for black and white TV uses only the Y parameter (I and Q are zero)

→ Largest bandwidth (4 MHz) is assigned to Y parameter.

→ Parameter I contains orange - cyan hue information that provides the flesh - tone shading and of the bandwidth (1.5 MHz).

→ Parameter Q carries green - Magenta hue information of the bandwidth (0.6 MHz).

→ An RGB signal can be converted to television signal by the following standard Matrix:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

That means if we want to convert any image on computer screen to TV image then for each pixel we have to multiply the given matrix.

and vice-versa can be done using.

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.000 & 0.956 & 0.620 \\ 1.000 & -0.272 & -0.647 \\ 1.000 & -1.108 & 1.705 \end{bmatrix} \cdot \begin{bmatrix} Y \\ I \\ Q \end{bmatrix}$$

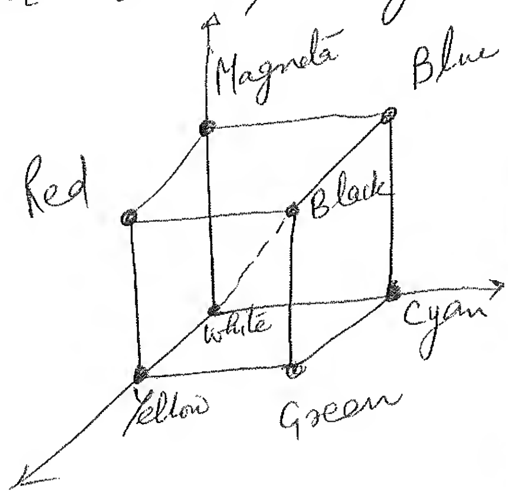
CMYK color model

→ stands for Cyan-Magenta-Yellow-Black

→ Generally used for Hard copy devices such as printers and plotters.

The RGB image can be converted to CMYK by following relationship:

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$



and vice-versa can be done

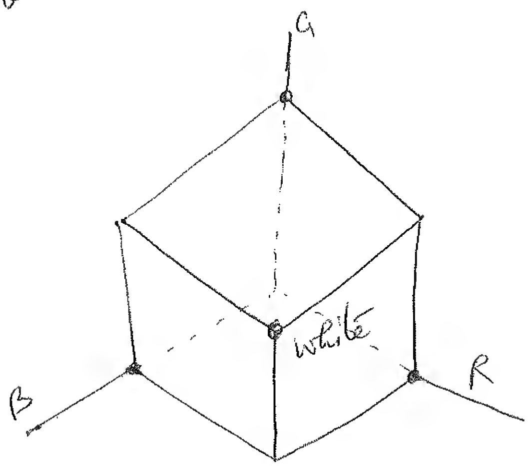
$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

HSV Color model

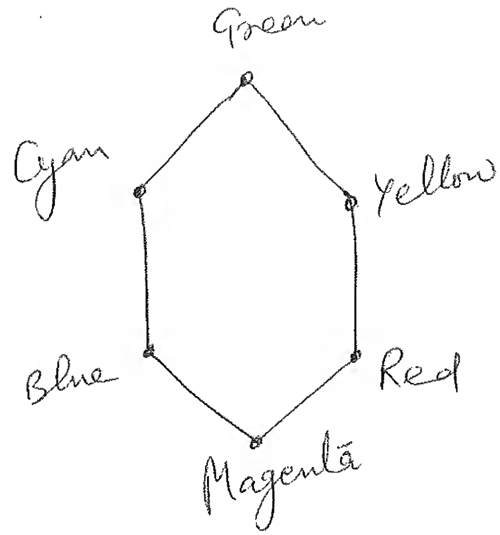
→ In RGB the amount of white and black is added to obtain the different shades.

→ The color parameters in this model are hue (H), saturation (S) and value (V).

→ The values HSV are derived from RGB cube.



RGB Color cube



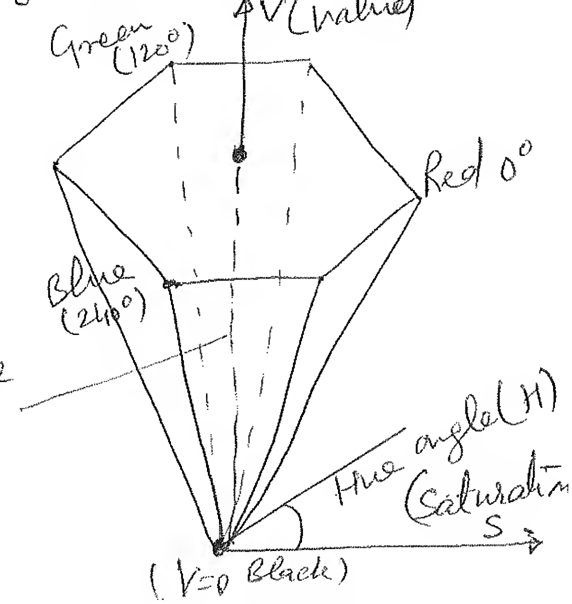
Color Hexagon

→ In the hexagone given below

→ Saturation is measured along horizontal axis and the value is measured along vertical axis through the center of the hexcone.

→ Hue is represented as the angle about the vertical axis, ranging from 0° at red through 360. vertices are seperated by 60° intervals.

→ Yellow is at 60°, green at 120° and cyan opposite red is H=180°



S = 0 (Gray scale)

S = 1 Maximum purity of the color.

S = 0.25 One quarter pure.

V = 1 for maximum purity.

Gray scale

→ At the top of the hexacone, colors have their maximum purity.

e.g. white is at the point $V = 1$ and $S = 0$.

The color shade can be produced by specifying various values of HSV.

Maximum value for H is 128.

Maximum value for S is 130

~~Maximum~~ value for V is $\underline{0 \le V \le 1}$.

using this model 16,384 various color shades can be available to the user and we need 14 bits per color to store a pixel color.

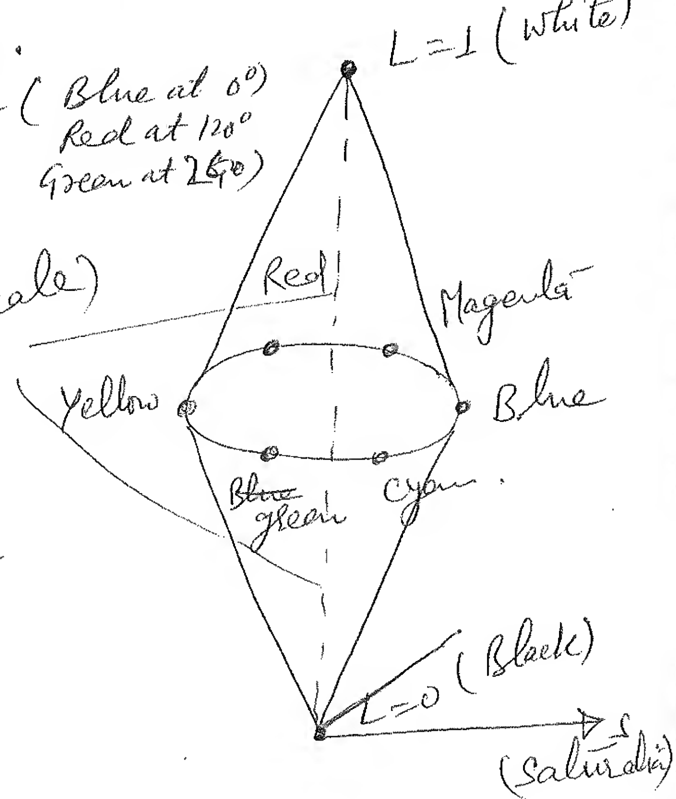
HLS color model

Hue – Lightness – Saturation

→ The vertical axis in this model is called as Lightness (L). At $L = 0$ we have black, and at $L = 1$ we have white.

→ Hue is defined by the angle (Blue at 0°
Red at 120°
Green at 240°)

To see the effect of HLS Model (gray scale) go in paintbrush and edit color option you can see the HLS values for various color shades.



(The HLS Cone)